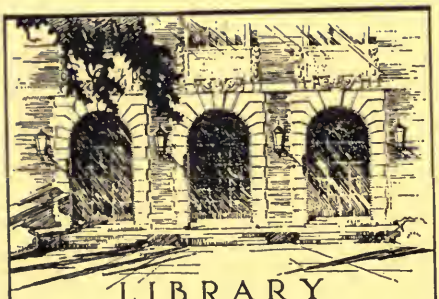

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BULLETIN No. 298

WINTER FORCING OF RHUBARB

By C. B. Sayre

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SUMMARY

In commercial rhubarb forcing heavy yields of dark pink stalks are desired. There is considerable variation in commercial practice and in opinions as to the best methods of obtaining these results.

In these experiments roots were forced in controlled temperature chambers and it was found that the lower the forcing temperature the darker red were the stalks and the slower the growth. At 59° F. maximum yields of well-colored stalks were obtained. An earlier crop of inferior color and lighter yield was produced at 68° F. Slow growing, dark red stalks and a light yield were produced at 50° F. No marketable stalks were obtained at 77° F. or above.

Forced rhubarb is over 95 percent water, yet many commercial growers do not water the roots during the forcing period for fear of "washing out the color." In these experiments watering increased the yields three-fold and did not "wash out" the color.

Roots of the same strain but different ages (one, two, three, five, and six years old) were forced under similar conditions. The one-year-old roots produced lighter colored stalks and smaller yields than the older roots. There was no appreciable difference in color of stalks produced by the two-, three-, five-, and six-year-old roots. Yields increased with the age of the roots up to three years. Above that age they were practically constant.

Some roots that had not been frozen were placed in the forcing cellar under the same conditions as similar roots that had been frozen. A prompt growth resulted from the latter, but there was no growth on the unfrozen roots. Later these were frozen and stimulated to growth.

To determine the effect of different freezing temperatures, roots were placed in cold storage chambers at 25°, 20°, 10°, and — 10° F. and later were forced under similar conditions. The roots did not freeze at 25° F., but at 20° they were frozen thoroly. Light freezing stimulated growth, but severe freezing was injurious and reduced the yield. Brief thoro freezing followed by a dormant period was as effective in stimulating growth as was freezing thruout the dormant period.

Soon after digging in the fall, roots of various ages were frozen for two weeks in cold storage chambers at 20°, 10°, and — 10° F. Half of each lot of roots was then forced immediately. The remainder of each lot was kept dormant for an additional month before forcing. Regardless of the freezing temperature, the roots of each lot which received the longer rest period produced a two to three-fold greater yield and made a more rapid growth than roots which had not been given the rest period. Severe freezing was not effective in shortening the rest period needed for maximum growth.

WINTER FORCING OF RHUBARB

By C. B. Sayre, Formerly Assistant Chief in Olericulture

Rhubarb forcing on a commercial scale is a profitable enterprise in Illinois and thruout the Northern states. In some localities in Illinois large areas are devoted to the growing of rhubarb roots exclusively for forcing. Many commercial gardeners find the enterprise a profitable means of using the surplus roots which are available whenever a rhubarb plantation is renewed.

Rhubarb thrives well in all sections of Illinois. Naturally a northern crop, it is not well suited to southern truck farming. Consequently to force it is by far the best method of producing it for early market in the North. The market for the forced product can be considerably developed in this state, particularly in the smaller cities.[1] The fact that forced rhubarb, when properly grown, is greatly superior to that grown out-of-doors increases the security of the commercial enterprise. It is much more attractive in color and appearance and is superior in texture and flavor, containing less acid. It is deep red or pink in color, and when cooked, produces a beautiful clear pink sauce. The stalks are unusually crisp, tender, and free from strings and woody fiber.

In addition to the commercial phase, rhubarb forcing is of importance to home gardeners and farmers, for a few rhubarb roots in the cellar will supply the home table with this delicious product during the winter months.

COMMERCIAL PRACTICES IN FORCING RHUBARB

Practices in forcing rhubarb vary somewhat with different producers, but the general principles are similar. When the rhubarb roots are grown exclusively for forcing, most of the growers prefer to use two-year-old roots, tho a few use one-year-old roots. When rhubarb is grown principally as an outdoor crop and forcing is considered only a side line by means of which the surplus roots are profitably utilized, the ones used for forcing are generally five or six years old or more.

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[1]In one farmers' retail public market in a medium-sized city in Illinois, it is not unusual to sell over a thousand pounds of forced rhubarb in a single market day. The only competition is rhubarb from California which is shipped to Illinois markets principally during the month of March. In 1925 125 carloads of California rhubarb were shipped to Chicago. However, rhubarb forced in Illinois can successfully compete with rhubarb shipped in from California because the forced rhubarb can be produced earlier in the winter, is of superior flavor, and can be marketed at less expense.

In any case, the roots are dug late in the fall and left outdoors until they have become thoroly frozen, after which they are ready for forcing. The roots should not be dug until the tops have died, because a translocation of food materials takes place and the more food material that is stored in the roots the greater will be the yield of forced rhubarb.

FIG. 1.—A FIVE-YEAR-OLD RHUBARB ROOT

Rhubarb produces large fleshy roots in which an abundance of food material is stored. By digging these roots after growth has stopped in the fall, and placing them under favorable conditions of temperature and moisture, the food material stored in them is utilized to produce forced rhubarb. The above roots were used in the experiment to determine the effect of different temperatures on the yield and color of forced rhubarb described on pages 59 to 61.

When the roots are left out to freeze, they should be covered with a little soil or straw to check excessive evaporation. The usual practice is to bed the roots on the surface of the ground in the forcing shed, which is left open and with the roof off until after the roots have become frozen.

Forcing structures differ widely in size and type of construction. Fig. 2 shows a very satisfactory type of forcing house. This house is of cheap construction and is dismantled at the end of the forcing season and erected in a new location the next year. In the fall the framework is erected and at digging time the roots are bedded within the area to be covered by the house. After the roots have become thoroly

frozen, the roof and sides are put on the house and the temperature raised by starting the stoves.

Small coal stoves, as shown in Fig. 3, are placed along the walls at intervals of about 40 feet. Each stove is placed just inside a door of the house, with room for a coal box and for firing. To make a more uniform distribution of heat, the stove pipes extend almost horizontally toward the center of the interval between stoves. They then run vertically thru the roof and appear outside in pairs, close together, altho their respective stoves are 40 feet apart. The arrangement of the pipes is shown in Fig. 2. One carload of coal was sufficient to maintain a satisfactory forcing temperature in this house thruout the forcing season.

FIG. 2.—A COMMERCIAL RHUBARB FORCING HOUSE

The roots were bedded in the fall within the area to be occupied. After they became frozen, the house was erected over them and forcing commenced. This house is 160 feet long and 48 feet wide. The ridge extending lengthwise thru the center is 6½ feet high and the eaves 5½ feet. It is made of second-hand lumber covered with tar paper. The frame is strong enough to sustain the weight of a layer of manure a foot deep over the roof. Manure is likewise banked up about 3 feet high around the sides. This maintains a more even temperature and greatly reduces the expense of heating. There are no windows, all harvesting being done by lantern light.

About 2 feet above the beds braces are nailed to the posts which support the roof. By laying a board across these braces, a "bridge" is provided from which the crop is harvested. In this way maximum cropping area is secured and no space is lost in aisles or alleys.

At the end of the forcing season this house is dismantled and removed and the lumber stacked for use the next season. The exhausted roots are then plowed under, which does away with the labor of removing them.

In these houses no flooring is used and the roots are bedded on the surface soil. Dirt is then filled in around the roots to the level of the crowns. By having no roof over them until the forcing season commences, the roots receive the full benefit of any rain or snowfall. This provides sufficient moisture to start growth when the temperature is raised.

Another type of forcing structure used by market gardeners is a celery storage house. The celery is out of the way before the rhubarb

forcing season commences and the dirt floor, well-insulated walls, and subdued light furnish favorable conditions for both crops. If a celery storage house is used for rhubarb, the rhubarb roots are dug before freezing weather and left in an exposed place to freeze until the celery is removed from the house. The rhubarb is then bedded on the dirt floor, as previously described.

FIG. 3.—SMALL COAL STOVES ARE USED FOR HEATING THE FORCING HOUSES

Eight of these stoves furnished sufficient heat for a house 160 feet long and 48 feet wide.

Regardless of the type of forcing house, the aim in commercial forcing is to produce large yields of deep red or pink-colored stalks. The deeper the red color, the more desirable is the product from a market standpoint. Forced rhubarb is harvested when the stalks are 18 inches or more long. The stalks are graded into three lengths (18, 20, and 22 inches) and are generally packed in boxes holding 20 pounds. The boxes are lined with paper and packed attractively, in keeping with the high quality of the product. The stalks are sometimes tied in bunches of three or four stalks, but usually are not bunched. They are sold by the pound.

Illinois markets prefer forced rhubarb grown in the dark or subdued light. In this case the leaf blades are very small and undeveloped, as shown in Fig. 5 and in the colored plate.

RHUBARB FORCED IN CELLAR FOR HOME USE

For home use rhubarb may be forced in a cellar, as shown in Fig. 5. After the roots have been frozen, they are bedded close together on the cellar floor and dirt is filled in around the roots. Ashes or sand may be used in place of soil, as the function of the soil is merely to hold moisture for the roots. Four or five large roots will supply all the rhubarb an average family will use during the winter. The roots should be placed in a darkened part of the cellar and protected from direct light. A subdued light does no harm, but direct light will result in large leaves and crooked stems, because the stalks will bend toward the light. By placing brown paper over the windows, a satisfactory subdued light may be secured that will not affect the growth.

EXPERIMENTS TO FIND BEST METHODS OF FORCING RHUBARB

The variation in commercial practices and in opinions in regard to the best methods of forcing rhubarb, together with the general lack of scientific data on the subject, prompted this series of experiments. Altho rhubarb forcing has been practiced for over half a century, not much has been written on the subject. A few popular articles have appeared from time to time, but most of the literature has been of a general nature and principally a description of commercial practices.

It therefore was the object of these investigations to obtain information in regard to the following points: (1) the effect of different temperatures on the yield and color of forced rhubarb, and the most favorable forcing temperature; (2) the effect of watering the roots, as a factor determining the yield and color of forced rhubarb; (3) the best age of roots for forcing; (4) the effect of different intensities of freezing and different lengths of freezing periods in breaking the rest period and increasing yields; and (5) the length of rest period needed to produce maximum yields.

EFFECT OF DIFFERENT TEMPERATURES ON YIELD AND COLOR OF FORCED RHUBARB

In the literature on rhubarb forcing there is a marked range in the recommendations as to the best forcing temperature. In fact, the principal treatise on rhubarb forcing says, "The temperature may vary from 45° to 80° or 90° according to circumstances."[1] Practices vary with different growers, some preferring a temperature of 50°, some 60°, and some using 75° F. As might be expected, yields and quality of product vary under these different temperatures.

To determine the effect of different temperatures on the yield and color of forced rhubarb some five-year-old roots that were of the same type and had been grown under identical conditions were selected for experiment (Fig. 1). From a large number of roots clumps were chosen of equal size and weighing 21 pounds each. These were bedded in forcing boxes and placed in special thermostatically controlled temperature chambers.[2] The chambers are electrically connected with heaters and refrigerating coils, so that a constant temperature may be maintained at all times regardless of exterior changes of temperature.

A selected rhubarb clump was placed in each of the following temperatures: 50°, 59°, 68°, 77°, and 86° F. These temperatures were maintained constantly thruout the forcing period. All the roots were

[1] The New Rhubarb Culture. J. E. Morse. 1901.

[2] These chambers are in the plant physiology laboratory of the Department of Botany, the author being permitted to use them thru the courtesy of Dr. C. F. Hottes. The experiments herein reported were conducted during the years 1922 to 1925.

bedded in the same way on March 30, and care was taken to see that other growing conditions were the same in each lot. Temperature, consequently, was the only factor in which the different lots varied, so that differences in yield and color of the forced rhubarb may be attributed to differences in the forcing temperature.

As each lot was harvested, the number of marketable stalks and their total weight were recorded. A typical specimen of each lot was selected and compared with the color charts in Ridgway's "Color Standards and Nomenclature," and an accurate color record thus obtained. Since the color is always darker near the base of the stalks and lighter at the top, the color at three places on each stalk was recorded; namely, 2 inches from the base, at the center, and 2 inches from the top of the stalk. In all cases it was the color on the exterior, or convex, side of the stalk that was recorded.

Different Temperatures Produce Striking Differences in Yield

Some striking differences will be noted in the yields of these lots, that were due to differences in forcing temperatures (Table 1).

Of the five temperatures used, 59° F. produced the largest yields. An earlier crop was produced at 68° F. but the yield was considerably less than at 59° F.

Temperatures of 77° and 86° F. proved excessive; weak, spindling growth resulting which quickly succumbed to soft rot. Unquestionably 77° F. is too high a temperature to maintain thruout the forcing period. Observations in commercial forcing houses show that this temperature may be tolerated for brief intervals without serious injury to the crop, but it is too high a temperature to maintain continuously.

Fifty degrees evidently is below the best forcing temperature. Altho a marketable crop of high quality was grown at this temperature, the growth was very slow and the yield was 23 percent less than at 59° F.

A comparison of the number of days it took the three lots to produce their crops of marketable stalks, and the number of days until the first picking, is shown by the following figures:

Lot 1—50° F. 87 days to produce crop, 33 days for first picking
Lot 2—59° F. 83 days to produce crop, 25 days for first picking
Lot 3—68° F. 62 days to produce crop, 18 days for first picking

As might be expected, the higher the forcing temperature, the quicker the crop was produced. Each 9 degrees increase in temperature brought the first picking 7 days earlier. The extremely rapid growth, however, did not yield the largest crop. As stated above, the most favorable temperature for large yields proved to be 59° F., altho 68° F. produced a much earlier crop. On the basis of both earliness

and yield, both of these higher temperatures proved better than 50° F., which was used for Lot 1.

Evidently the temperature used in forcing rhubarb is an important factor affecting both the total yield and the rate of growth.

TABLE 1.—YIELDS OF RHUBARB AT DIFFERENT FORCING TEMPERATURES
(Five-year-old roots. Frozen in field all winter, dug March 23, bedded March 30)

Date	Lot 1, forced at 50°F.; marketable stalks produced		Lot 2, forced at 59°F.; marketable stalks produced		Lot 3, forced at 68°F.; marketable stalks produced	
	Number	Weight	Number	Weight	Number	Weight
		grams		*grams*		*grams*
Apr. 16.....	.....	...	...	...	4	221
Apr. 18.....	...	...	...	...	11	487
Apr. 20.....	...	...	...	...	8	315
Apr. 23.....	...	...	9	399	8	301
Apr. 27.....	...	...	6	355	12	451
Apr. 30.....	...	...	10	485	7	271
May 2.....	6	247	5	169	14	438
May 4.....	4	171	8	326	5	148
May 7.....	3	101	3	139	7	262
May 11....	7	267	7	359	11	360
May 16....	12	450	10	389	12	331
May 21....	4	223	9	391	7	200
May 26....	9	368	13	383	6	165
May 31....	8	354	8	272	3	80
June 5.....	5	176	7	251	...	...
June 14....	11	499	13	332	...	...
June 21....	11	349	7	158	...	...
June 25....	5	154	...	...	...	...
Total....	85	3 359 or 7 lbs. 6 oz.	115	4 408 or 9 lbs. 11 oz.	115	4 030 or 8 lbs. 14 oz.

Lots 4 and 5, forced at 77° and 86° F. respectively, did not produce any marketable rhubarb. The growth was weak and spindling and in two weeks collapsed from soft rot. Apparently these temperatures are too high for healthy growth. Shoots appeared first in Lot 3, followed in order by Lots 4, 2, 5, and 1.

Lower Temperatures Result in Deeper Color

Color is an important factor in the market value of forced rhubarb. The more red or dark pink in the stalks the more attractive their appearance and the higher the price they will command. The color is retained in the cooked rhubarb and adds greatly to its attractiveness when served.

In Table 2 are given accurate color records of the yields produced by Lots 1, 2, and 3. Three points should be noted, namely:

1. The lower the forcing temperature, the darker red is the rhubarb produced, and this relative difference persists thruout the forcing period.

2. At 50° F. the deep red color extends the full length of the stalk. This valuable characteristic continued thruout the forcing period. The

TABLE 2.—COLOR RECORD OF RHUBARB FORCED AT DIFFERENT TEMPERATURES

Date	2 inches from base of stalk	Center of stalk	2 inches from top
Lot 1. Forced at 50°F.			
May 2	Carmine	Carmine	Carmine
May 4	Scarlet red	Spectrum red	Spectrum red
May 7	Carmine	Carmine	Nopal red
May 11	Carmine	Carmine	Carmine
May 16	Carmine	Carmine	Carmine
May 21	Ox blood red	Ox blood red	Carmine
May 26	Nopal red	Nopal red	Nopal red
May 31	Scarlet red	Scarlet red	Rose doree
June 5	Scarlet red	Spectrum red	Rose doree
June 14	Scarlet red	Scarlet red	Rose doree
June 21	Spectrum red	Rose doree	Geranium pink
June 25	Scarlet red	Rose doree	Rose doree
Lot 2. Forced at 59° F.			
Apr. 23	Scarlet red	Spectrum red	Rose doree
Apr. 27	Scarlet red	Rose doree	Geranium pink
Apr. 30	Scarlet red	Rose doree	Shrimp pink
May 2	Rose doree	Geranium pink	Martius yellow
May 4	Scarlet red	Rose doree	Shrimp pink
May 7	Scarlet red	Begonia rose	La France pink
May 11	Spectrum red	Scarlet red	Rose doree
May 16	Scarlet red	Rose doree	Rose doree
May 21	Spectrum red	Rose doree	Geranium pink
May 26	Spectrum red	Rose doree	Shrimp pink
May 31	Rose doree	Geranium pink	Shrimp pink
June 5	Begonia rose	Begonia rose	Geranium pink
June 14	Rose doree	Rose doree	Orient pink
June 21	Rose doree	Geranium pink	Shrimp pink
Lot 3. Forced at 68° F.			
Apr. 20	Scarlet	Rose doree	Shrimp pink
Apr. 23	Scarlet	Rose doree	Shrimp pink
Apr. 27	Rose doree	Geranium pink	Shrimp pink
Apr. 30	Rose doree	Geranium pink	Shrimp pink
May 2	Geranium pink	Shrimp pink	Baryta yellow
May 4	Rose doree	La France pink	Shrimp pink
May 7	Geranium pink	Eosine pink	Baryta yellow
May 11	Begonia rose	La France pink	Shrimp pink
May 16	Geranium pink	Shrimp pink	Sulfur yellow
May 21	Rose doree	La France pink	Sulfur yellow
May 26	Eosine pink	Shrimp pink	Sulfur yellow
May 31	Geranium pink	Shrimp pink	Sulfur yellow

NOTE.—For the benefit of those who do not have available plates of standard colors and nomenclature, it should be said that ox blood red, nopal red, carmine, scarlet red, and spectrum red are all deep shades of red, and that rose doree, begonia rose, geranium pink, La France pink, and shrimp pink are shades of pink ranging from dark to light in the order named. Stalks typical of the colors produced at the different temperatures are shown in the accompanying colored plate.

red color also extended into the large veins of the leaves, while at higher temperatures only yellow and light green appeared in the leaves.

3. The red color becomes less intense as the harvesting season continues. This should be noted also in the records of Lots 6, 7, 8, and 9, Tables 4 and 6.

Since the color of the rhubarb forced at 59° F. was entirely satisfactory, and the yield was 30 percent greater (by weight) and the growth quicker than at 50° F., it would seem best for growers to use the higher temperature under most circumstances. At 68° F. the temperature was evidently above the optimum, for altho the growth was quicker the yield was less and the color was considerably inferior.

YIELD AND COLOR AS AFFECTED BY WATERING

Many commercial growers produce the entire crop of forced rhubarb without watering the roots at all during the forcing period. This method is commonly practiced where the roots are bedded in the open in the fall or where the roof is left off the forcing house until after the roots have frozen. In this way the roots and the soil packed around them receive the full benefit of any rain or snowfall until the roof is put on and the forcing period commences. Some growers claim that this furnishes sufficient moisture for good yields of forced rhubarb, making additional expense for watering unnecessary. Others claim that watering the roots during the forcing period will "wash out" the color and therefore is undesirable since the darker red stalks bring the higher price.

Since the marketable product of forced rhubarb is over 95 percent water, and since this forced growth results when water is taken up by the roots and the food materials stored in the roots thus utilized, it seemed to the author that timely watering during the forcing period would increase the yields. Accordingly the following test was made in order to determine if watering the roots during the forcing period would increase the yields and whether it would result in paler, less desirable stalks.

From a large number of five-year-old rhubarb clumps, twelve were selected that were of equal size and weight. These were all of the same variety and had been grown under similar conditions in the garden. These large, uniform clumps were divided into two lots of six each and on March 30 were bedded in moist soil in adjacent sections of the forcing cellar. These lots were grown and forced under identical conditions except that one lot, No. 6, was watered at timely intervals during the forcing period, while the other lot, No. 7, was not watered. No schedule was followed in watering Lot 6, the water being applied whenever the soil seemed dry and it was thought watering would be beneficial. All of these roots had been frozen in the field, where they

PLATE I

Typical color of stalks at different forcing temperatures.

A and C—Forced at 59° F.
B and D—Forced at 68° F.
E —Forced at 50° F.

The lower the forcing temperature the slower the growth and the darker the color. At low temperatures the red or dark pink color extends the full length of the stalks and into the veins of the leaves. A deep pink color is preferred in the markets. At 59° F. the largest yield was produced and the stalks were of good marketable color.

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received full benefit of rain and snowfall. They were dug before growth started in the spring and were immediately bedded in moist soil in the forcing cellar.

Watering Increases Yield

The stalks were harvested as they reached marketable size and a record was kept of the number of marketable stalks and total weight of each harvest (Table 3).

The result of watering Lot 6 was that the yield was increased threefold. At 15 cents a pound, which is an average wholesale price,

TABLE 3.—EFFECT OF WATERING ON YIELD OF FORCED RHUBARB
(Five-year-old roots, 6 in each lot. Frozen in field all winter, dug March 23, bedded March 30. Forced at 55° F.)

Date	Lot 6, watered during forcing; marketable stalks produced		Lot 7, not watered; marketable stalks produced	
	Number	Weight	Number	Weight
		lbs. oz.		*lbs. oz.*
Apr. 26	16	2— 6	..	.....
Apr. 28	29	4— 2	..	.....
May 1	34	5— 1	13	2
May 4	34	4— 9	17	1—15
May 8	39	4— 9	13	1— 9
May 12	37	3—13	15	1— 7
May 16	44	3—12	22	1—14
May 26	54	5— 4	18	1— 8
June 6	54	3— 4	24	1—10
Total	341	36—12	122	11—15
Average yield per root		6— 2	..	2

it may be said that timely watering increased the returns 62 cents a root. All the other lots included in these experiments were watered during the forcing period, and this treatment doubtless was a factor in the large average yields produced in most of the lots.

Color Not "Washed Out" by Watering

The benefit of increased yields resulting from watering would be greatly offset if watering had a tendency to "wash out" the color of the marketable product. Consequently an accurate record of the color of the stalks produced at each harvest period is of significant commercial value. This is given in Table 4.

At the end of the harvesting season the stalks from Lot 7 (unwatered) were of a darker red than the stalks from Lot 6. However, it is necessary to consider another factor in this connection, namely, that as the roots become exhausted the stalks produced are of a less intense red. Since the roots that had been watered produced over three

times as much marketable rhubarb as the unwatered roots, it is to be expected that at the end of the season the roots in Lot 6 would be more exhausted, and therefore would produce lighter colored stalks than Lot 7. This is substantiated by the fact that when Lot 6 had produced 2 pounds of marketable rhubarb per root (equal to the total yield of Lot 7), the color of the stalks was practically the same dark pink as were those in Lot 7 at the end of the season. It would therefore seem that watering the roots during the forcing period did not "wash out" the color of the stalks. It should be noted that the watered roots produced a heavy crop of good marketable color and grade thruout.

A word of caution in regard to over-watering might be mentioned. The same principles would apply in watering forced rhubarb as in

TABLE 4.—COLOR RECORD OF RHUBARB WHEN WATERED AND WHEN NOT WATERED

Date	2 inches from base	Center of stalk	2 inches from top
Lot 6. Watered during forcing			
Apr. 26	Rose doree	Rose doree	La France pink
Apr. 28	Scarlet red	Rose doree	La France pink
May 1	Scarlet red	Scarlet red	La France pink
May 4	Scarlet red	Rose doree	Shrimp pink
May 8	Scarlet red	Geranium pink	Sulfur yellow
May 12	Spectrum red	Rose doree	Shrimp pink
May 16	Rose doree	Rose doree	Shrimp pink
May 26	Rose doree	Geranium pink	Sulfur yellow
June 6	Rose doree	Geranium pink	Sulfur yellow
Lot 7. Not watered			
May 1	Scarlet red	Rose doree	Shrimp pink
May 4	Nopal red	Scarlet red	La France pink
May 8	Nopal red	Scarlet red	Shrimp pink
May 12	Ox blood red	Nopal red	Shrimp pink
May 16	Nopal red	Nopal red	La France pink
May 26	Ox blood red	Carmine	Shrimp pink
June 6	Spectrum red	Geranium pink	Shrimp pink

watering any other forced crop; namely, to water thoroly at each watering, avoiding frequent light sprinklings which would tend to maintain a moist surface and favor the development of disease organisms.

BEST AGE OF ROOTS FOR FORCING

The best age of rhubarb roots for forcing cannot be determined merely by comparing the yields produced. Various other factors must be considered, such as the cost of growing the roots of each age, the added returns from outdoor harvesting, costs of digging roots, and earliness and quality of stalks from roots of each age, and whether

the roots are grown primarily for forcing or whether the forcing is a side line incidental to field growing.

In order to obtain some information in regard to the yield and quality of rhubarb from roots of different ages, the following investigations extending over three seasons were undertaken. The results indicate the yields that may be expected from well-grown roots of each age.

Five-Year Roots Prove Superior to One-Year Roots

During the first season only one-year-old roots and five-year-old roots were included in the experiment (Table 5). These were dug on March 23, and twenty-five uniform clumps of each age selected. They had all been frozen in the field during the winter and were dug before growth started in the spring. The next day both lots were bedded in

TABLE 5.—YIELDS OF RHUBARB FROM ROOTS OF DIFFERENT AGES
(Twenty-five roots in each lot. Frozen in field all winter, dug March 23, bedded March 24. Forced at 55° F.)

Date	Lot 8, one-year-old roots; marketable stalks produced		Lot 9, five-year-old roots; marketable stalks produced	
	Number	Weight	Number	Weight
		lbs. oz.		*lbs. oz.*
Apr. 17	99	18— 2	76	11— 2
Apr. 20	48	9— 2	85	12—12
Apr. 23	114	16— 4	172	25— 2
Apr. 26	40	4—15	63	9
Apr. 28	45	5—14	55	8— 6
May 1	47	5— 7	143	17—12
May 4	82	8— 6	90	11
May 8	65	5— 4	76	7—10
May 12	39	2— 9	75	6—14
May 16	31	2— 4	89	7— 5
May 26	19	1— 4	117	9
June 6	..	.....	37	2— 9
Total	629	79— 7	1,078	128— 8
Average yield per root		3.18 lbs.	..	5.14 lbs.

adjacent sections of the forcing cellar and placed under identical forcing conditions at a temperature of approximately 55° F. A typical root of each of these lots is shown in Fig. 4; Fig. 5 shows the two lots growing in the forcing cellar.

On April 17 the first stalks were harvested from these lots. The last marketable stalks from the one-year roots were harvested on May 26; the five-year roots produced one more pulling on June 6. The total yields of the two lots are shown in Table 5, and the color record of the stalks in Table 6. The stalks produced by the one-year roots were a much lighter pink than those produced by the five-year roots.

The five-year-old roots produced an average of 2 pounds of marketable rhubarb more per root than did the one-year-old roots. Likewise the color, and consequently the value, of the product from the

FIG. 4.—TYPICAL ROOTS FROM LOTS 8 AND 9

At the left is a one-year-old root from Lot 8, at the right a five-year-old root from Lot 9.

FIG. 5.—TYPICAL GROWTH FROM LOTS 8 AND 9

The five-year-old roots (Lot 9) at the right produced heavier, darker-colored stalks than the one-year-old roots (Lot 8) at the left.

five-year-old roots was considerably superior to that produced by the one-year-old roots. Taking color and yield into consideration, the five-year-old roots were better than the one-year-old roots for forcing. From the standpoint of expense also, the older roots are to be pre-

TABLE 6.—COLOR RECORD OF RHUBARB GROWN FROM ROOTS OF TWO DIFFERENT AGES
(Roots forced at 55° F.)

Date	2 inches from base of stalk	Center of stalk	2 inches from top of stalk
Lot 8. Grown from one-year-old roots			
Apr. 20	Geranium pink	Coral pink	Shrimp pink
Apr. 23	Begonia rose	Geranium pink	Shrimp pink
Apr. 26	Eosine pink	La France pink	Orient pink
Apr. 28	Eosine pink	La France pink	Pale salmon pink
May 1	Eosine pink	La France pink	Sulfur yellow
May 4	La France pink	Shrimp pink	Massicot yellow
May 8	Shrimp pink	Shrimp pink	Sulfur yellow
May 12	Shrimp pink	Pale green-yellow	Pale green-yellow
May 16	Shrimp pink	Sulfur yellow	Sulfur yellow
May 26	Shrimp pink	Sulfur yellow	Sulfur yellow
Lot 9. Grown from five-year-old roots			
Apr 20	Scarlet	Eosine pink	Shrimp pink
Apr. 23	Scarlet red	Begonia rose	Eosine pink
Apr. 26	Rose doree	Rose doree	La France pink
Apr. 28	Rose doree	Rose doree	Shrimp pink
May 1	Geranium pink	Geranium pink	Shrimp pink
May 4	Geranium pink	La France pink	Martius yellow
May 8	Rose doree	Eosine pink	Sulfur yellow
May 12	Rose doree	Geranium pink	Shrimp pink
May 16	Geranium pink	Geranium pink	Shrimp pink
May 26	Geranium pink	La France pink	Sulfur yellow
June 6	Rose doree	Rose doree	Sulfur yellow

ferred. From the second year on, a rhubarb plantation should produce sufficient income from the field crops to pay for the roots, but no income will have been obtained from one-year old roots.

Second Year's Test Shows Effect of Rest Period

During the second year of this experiment, one-, two-, and six-year-old roots were forced (Table 7). The clumps were all dug on November 21. Six lots of roots were selected, each consisting of ten roots. All roots were as uniform as it was possible to select. They were all of the same variety and strain and had been grown under similar conditions in the field.

Lots 10, 11, and 12, consisting of one-, two-, and six-year roots respectively, were kept in a cold storage chamber at 20° F. for two weeks, being put into the freezing temperature on November 23 and removed December 7. They were bedded in adjacent sections of the forcing cellar on December 10 and grown under identical forcing conditions, the forcing temperature being approximately 58° F.

The other three lots, all six-year roots, were treated somewhat differently. Lot 13 was frozen for one week only, having been re-

moved from the refrigerating room on November 30. Lot 14 was not frozen at all at this time. Both Lots 13 and 14 were bedded with Lots 10, 11, and 12, on December 10.

On January 10, one month later, Lot 14 was removed from the forcing cellar and taken outside for ten days to freeze. There had been no sign of growth on any of the roots of this lot, while on the other four lots in the forcing house vigorous growth had commenced and shoots 10 inches high were already produced on each. Lot 14 was again bedded on January 21, in the forcing cellar, and Lot 15, which had been left outdoors to freeze for eight weeks, was also bedded at this time.

No color records were kept of this group of experiments, but the yields are recorded in Table 7.

TABLE 7.—YIELDS OF FORCED RHUBARB FROM ROOTS OF DIFFERENT AGES
(Ten roots in each lot, bedded December 10. Forced at approximately 58° F.)

Lot	Age of roots	Length of freezing	First picking	Last picking	Total yield	Yield per root
					lbs. oz.	*lbs.*
10	1 year.....	2 weeks at 20°...	Jan. 21	Feb. 26	22— 4	2.22
11	2 years.....	2 weeks at 20°...	Jan. 25	Feb. 26	14—13	1.48
12	6 years.....	2 weeks at 20°...	Jan. 28	Feb. 21	18—15	1.90
13	6 years.....	1 week at 20°....	Jan. 21	Mar. 10	23— 8	2.35
14	6 years.....	Tried unfrozen, later frozen[1]...	Mar. 10	Apr. 8	10— 2	1.16
15	6 years.....	8 weeks outdoors[2]	Feb. 26	Apr. 8	54— 9	5.45

[1]No growth resulted after one month in forcing temperature. Removed on January 10 for freezing and rebedded on January 21.

[2]Bedded January 21.

NOTE.—The low yield of all lots except No. 15 apparently was due to the roots not having sufficient rest period before being forced. Consequently, these results should be disregarded as a test of the best age of roots for forcing.

The disappointingly low yields from Lots 10, 11, and 12, having identical treatment, and from Lot 13, which was subjected to a shorter freezing period but otherwise treated the same, would indicate that some other factor than age affected the yields. As a test of age, therefore, no significance can be attached to the differences in yield. This is substantiated by comparing the yield of Lot 15 with the yields from Lots 12 and 13, all of which were of the same kind and age. The fact that Lot 15 produced about two and one-half times as much as either of the other lots would indicate that in the first four lots either the rest period was too short or that the roots were not sufficiently frozen. Whichever the cause, the results for this season must be disregarded as a test of the best age of root to use for forcing.

Yields Increase With Age Up to Three Years

In planning the experiments for the third season, the variable factors entering into the previous year's experiments were taken into account and included in additional comparisons.

By selecting the plants early in October, before the tops died in the field, it was possible to select those that had produced large stalks of deep red color. On November 21 the roots of these plants were dug. One-, two-, three-, and seven-year-old roots were used. Typical one-, two-, and three-year roots are shown in Fig. 6.

Five clumps of each age were placed in cold storage at —10° F. for five days. After being thawed out slowly, these roots were bedded in adjacent sections in the forcing cellar on December 17, and designated as Lots 16, 17, 18, and 19 (Table 8).

TABLE 8.—YIELDS OF FORCED RHUBARB FROM ROOTS OF DIFFERENT AGES AND WITH VARYING REST PERIODS

(Five roots in each lot. Forced at approximately 58° F.)

Lot	Age of roots	Length of freezing	Time of growth	First picking	Last picking	Total yield	Yield per root
			days			*lbs. oz.*	*lbs.*
Roots forced after brief rest and freezing. Bedded December 17							
16	1 year	5 days at 10° F.	41	Jan. 27	Feb. 28	10— 3	2.03
17	2 years	5 days at 10° F.	38	Jan. 24	Feb. 28	24— 7	4.9
18	3 years	5 days at 10° F.	41	Jan. 27	Feb. 28	9—13	1.95
19	7 years	2 weeks at–10°F	47	Feb. 5	Feb. 28	5— 8	1.1
Roots forced after six weeks' rest period. Bedded January 17							
20	1 year	6 weeks outdoors	28	Feb. 14	Mar. 25	30—10	6.2
21	2 years	6 weeks outdoors	30	Feb. 16	Apr. 4	38—14	7.8
22	3 years	6 weeks outdoors	30	Feb. 16	Apr. 4	47—10	9.75
23	7 years	6 weeks outdoors	28	Feb. 14	Apr. 4	45—15	9.2

Five clumps of each age were left outdoors exposed to freezing temperatures for about six weeks, during which time the temperature went below zero several times, the minimum reached being —20°. On January 15, roots of this group were bedded in adjacent sections in the forcing cellar. These are designated as Lots 20, 21, 22, and 23.

As in the previous season, the roots that were forced after a very brief rest period (Lots 16, 17, 18, and 19) produced low yields. It would seem that the lack of a sufficient rest period influenced the yields to such an extent that it overshadowed the effect of differences due to age of root.

The results from the series that had sufficient rest period (Lots 20, 21, 22, and 23) probably give the most accurate index of differences in yields due to differences in age of roots. The one-year roots

in this group produced the smallest yields, the yields increasing with the age of the roots up to three years. The seven-year roots produced practically the same as the three-year roots. Observations by the author, of a large number of roots grown under various conditions and seasons, bear out this experience. Two- and three-year roots produce the largest stalks and the most vigorous growth, and it is doubtful if older roots produce appreciably larger yields. As the plants become older, the stalks become smaller and often more numerous.

Altho accurate color records were not kept of these lots, the one-year-old roots produced stalks that were appreciably lighter in color than those produced by older roots, similar to results secured with Lots 8 and 9.

FIG. 6.—TYPICAL ONE, TWO, AND THREE-YEAR-OLD ROOTS USED IN LOTS 20, 21, AND 22

When grown exclusively for forcing, two-year-old roots are best, considering yields and costs of production. When forcing is done as a supplement to field culture, the aged roots (six or seven years old) which are available will give large profitable yields of well-colored stalks.

The larger yields and darker colored stalks produced by two-year-old roots as compared with one-year-old roots would make the two-year roots preferable for commercial forcing. However, one has to consider the expense of caring for the roots another year in the field, the slower turnover of capital, the charge for the use of land another year, the increased labor of digging the larger roots, and the larger space required in the forcing house.

To counteract the additional expense of producing the two-year-old roots, some commercial growers harvest a light crop from these roots in the field at the beginning of their second year. This is generally limited to one or two pullings as soon as the stalks have reached marketable size. At this time the price is high, and a light harvest will pay the expense of caring for the crop for that year. A heavy pulling should not be made, as this would seriously weaken the roots and reduce the yield of forced rhubarb. After the second year a good crop

may be harvested each spring from the rhubarb plantation, and this will more than offset the additional year's expense for the roots. Consequently there is no additional cost for roots over two years old. Furthermore, after a plantation has reached full bearing age (three years) it is generally more profitable not to disturb it or use the roots for forcing until the plantation needs to be renewed. After five or six years, however, the yields will decrease and the roots will have to be divided and replanted to renew the vigor of the plants. This leaves a surplus of old roots, which can be used profitably for forcing.

If roots are grown principally for forcing, there would be no need of growing the roots more than two years. It would seem from these experiments that two-year-old roots are preferable to one-year-old roots for this purpose. This is also in accordance with the practice of many commercial growers. However, in cases where a good market for outdoor rhubarb is available, the most profitable practice would be to use old roots (six or seven years old) for forcing. These would be obtained from the surplus when the old plantation was renewed by dividing and replanting the divisions of the old roots. By renewing a portion of the plantation each year there would be a constant supply of large old roots for forcing.

EFFECT OF INTENSITY AND LENGTH OF FREEZING IN BREAKING REST PERIOD AND INCREASING YIELD

It is a well known fact that rhubarb cannot be forced successfully until the roots have first been thoroly frozen. Apparently freezing causes certain physiological changes and breaks the rest period, as a result of which the roots are stimulated to a vigorous growth when given favorable conditions of temperature and moisture.

That the length of the dormant period before forcing might also be an important factor affecting the yield of forced rhubarb was suggested by the striking differences in the yields of Lots 12 and 15, Table 7, and the low yields of Lots 10, 11, 12, and 13, Table 7, compared with those from Lots 1, 2, and 3, Table 1, and from Lots 8 and 9, Table 5.

The experiments for the third season (1924-25) therefore were so planned that the effects of these factors might be determined.

From a lot of selected seven-year-old roots of the same variety and strain, that had been grown under identical conditions, twenty-five clumps were selected of uniform size. These were dug on November 21. They were divided into five lots of five clumps each. These lots were placed in cold storage on December 6.

Lots 25 and 28 were placed in a temperature of 25° F. It was thought that this temperature would freeze the roots lightly. However, after 72 hours at this temperature the roots remained unfrozen. Consequently the temperature was reduced on December 9 to 20° F. On December 10 this storage chamber was not properly regulated and the

temperature dropped to 2° F., but within 24 hours was back to 20° F. and was kept constant at this temperature for the remainder of the cold storage period.

Lots 26 and 29 were subjected to a temperature of 10° F. thruout the cold storage period.

Lot 30 was subjected to a temperature of —10° F. thruout the cold storage period. Lot 19, described in the previous test, is brought into the comparison at this point as a companion to Lot 30, since it had the same history and treatment with the exception of a longer rest period.

On account of the unintentional lowering of the temperatures in Lots 25 and 28, two other lots of the same kind of roots were placed in cold storage on December 12, 1924. These were designated as Lots 24 and 27 and were subjected to a constant temperature of 20° F. thruout the cold storage period.

TABLE 9.—EFFECT OF INTENSITY OF FREEZING AND LENGTH OF REST PERIOD UPON YIELDS OF FORCED RHUBARB

(Five roots in each lot, seven years old. Forced at approximately 58° F.)

Lot	Length and severity of freezing	Time of growth	First picking	Last picking	Total yield	Yield per root
	Roots forced immediately after freezing. Bedded December 17					
		days			*lbs. oz.*	*lbs.*
24	2 weeks at 20° F.....	33	Jan. 27[2]	Mar. 25	38— 2	7.62
25	2 weeks at 20° F[1].....	38	Jan. 24	Mar. 18	33—12	6.75
26	2 weeks at 10° F.....	38	Jan. 24	Mar. 18	28— 4	5.65
19	2 weeks at —10° F.....	47	Feb. 5	Feb. 28	5— 8	1.10
	Additional rest period at 31° for 1 month before forcing. Bedded January 17					
27	2 weeks at 20° F.....	26	Feb. 12	Apr. 17	65—10	13.12
28	2 weeks at 20° F[1].....	26	Feb. 12	Apr. 4	63—10	12.68
29	2 weeks at 10° F.....	26	Feb. 12	Apr. 4	75	15.00
30	2 weeks at —10° F.....	26	Feb. 12	Apr. 4	16— 7	3.3
23	6 weeks outdoors.....	28	Feb. 14	Apr. 4	45—15	9.2

[1]The temperature in this chamber dropped to 2° F. on December 10, as a result of improper regulation, but within 24 hours was back again to 20° F.

[2]Bedded one week later.

After two weeks in the freezing chambers, Lots 24, 25, 26, and 19 were removed from their freezing chambers and bedded in adjacent sections of the forcing cellar on December 17. At the time these lots were removed from their freezing chambers their companion lots (Lots 27, 28, 29, and 30) were likewise removed from their freezing chambers and were placed in cold storage at 31° F. for one month. At this temperature they thawed out but remained dormant. After this additional rest period, these lots were bedded on January 17 in the same forcing cellar with their companion lots and forced under similar conditions. (Table 9)

Lot 23 also is brought into this comparison, since it was of the same age and received the same treatment except that it had been left outdoors to freeze during this six weeks' period. During this time the temperature went below zero on several occasions, the minimum being — 20° F. This lot was likewise bedded in the forcing cellar on January 17.

Any differences in the yields of Lots 24, 25, 26, and 19 may reasonably be attributed to the effect of different freezing temperatures, that being the only essential difference in their treatment. Differences among Lots 27, 28, 29, and 30 likewise may be attributed to this factor, since it was the only essential one in which they varied.

In both these series a light freezing, two weeks at 20° F. (Lots 24 and 27), appeared to be sufficient to break the rest period. This is shown by the prompt growth in comparison with the unfrozen roots of Lot 14 in Table 7. Furthermore very severe freezing, two weeks at — 10° F. (Lots 19 and 30), seemed to injure the roots, for in each case the yields decreased where the freezing was more intense.

Altho the light freezing was sufficient to cause the physiological changes resulting in prompt growth under forcing conditions, large yields were not obtained from any roots, regardless of the intensity of freezing, which were allowed only a short rest period. This suggested that the length of rest period might be a factor affecting yields.

LENGTH OF REST PERIOD FOR MAXIMUM YIELDS

An examination of Tables 8 and 9 shows eight direct comparisons in which length of rest period was the only variable factor (in Table 8 compare Lot 16 with Lot 20, 17 with 21, 18 with 22, and 19 with 23; in Table 9 compare Lot 24 with Lot 27, 25 with 28, 26 with 29, and 19 with 30). In every case the yields were increased from two to threefold and the resulting growth was more rapid where the roots had a longer rest period. The results are conclusive in showing that the length of the rest period is a most important factor affecting yields and rapidity of growth; and that a rest period of at least six or eight weeks is essential to maximum yields.

Apparently a rest period of this length is necessary for certain physiological changes to take place in the roots before maximum growth will result. Altho freezing is necessary to break this rest period (Lot 14, Table 7), a light freezing is sufficient to break it so that growth will start promptly (Lots 24 and 27, Table 9). Severe freezing is only injurious and is not effective in reducing the rest period needed for maximum growth (Lots 25, 26, and 19, and 28, 29, and 30, Table 9).

CONCLUSIONS

1. Temperature is an important factor affecting both the yield and color of forced rhubarb. The lower the forcing temperature, the slower the growth and the more red or dark pink color in the stalks. Slow growing, dark red stalks can be produced at a forcing temperature of 50° F. Taking into consideration yield, color and rate of growth, the optimum forcing temperature is about 59° F. At this temperature large yields of well-colored stalks can be produced. A quicker crop can be grown at 68° F. but the color will be inferior. Seventy-seven degrees F. is too high for healthy growth.

2. Watering the roots abundantly during the forcing period greatly increases the yield and does not reduce the red color of the stalks.

3. Rhubarb roots one-year old or older can be used for forcing. One-year-old roots produce the lightest colored stalks and smallest yields. Yields increase with the age of the roots up to three years. When roots are to be grown exclusively for forcing, one-year or two-year roots are best, the latter having the advantages of heavier yield and better color to offset the increased cost of the roots. Aged roots (five to seven years old) which are available whenever a plantation is replanted, produce large profitable yields of well-colored stalks.

4. Freezing the roots, thus causing certain physiological changes that stimulate growth, is essential before rhubarb can be forced profitably.

5. A light freezing (20° F. for two weeks) is sufficient to cause the physiological changes which stimulate growth. The roots do not freeze at 25° F.

6. Severe freezing (— 10° F.) is injurious, reduces the yield, and does not shorten the rest period needed for maximum yields.

7. A brief, thoro freezing (two weeks at 20° F.) followed by a dormant period (an additional four weeks at temperature too low for growth) is as effective in stimulating growth as continuous freezing thruout the same period.

8. The length of the rest period before forcing is an important factor affecting yields. In general, the longer the rest period, the greater the subsequent yield and the more rapid the growth. A rest period of at least six or eight weeks is essential for maximum yields.

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